Description

SYSTEM FOR AGGLOMERATING EXHAUSTED PARTICULATE MATTER

Technical Field

[01] The present invention is directed to a method and device for agglomerating particulate matter exhausted by an engine.

Background

[02] The operation of many types of engines generates particulate matter of varying sizes and weights. This particulate matter, which is typically carbon in the form of ashes or soot, is generated when the fuel supplied to the engine is combusted. The engine expels this particulate matter from the combustion chamber along with other engine exhaust. Unless this particulate matter is filtered or otherwise removed from the engine exhaust, these particulates will be vented to the environment. However, particulate matter has been identified as a pollutant that may pose hazards to the environment. Accordingly, regulations have been enacted to place limits on the size and amount of particulate matter that may be exhausted from an engine.

[03] To remove particulate matter from engine exhaust, an exhaust filtration system is typically disposed within the exhaust line. These exhaust filtration systems may include a particulate filter or trap that removes particulate matter from the engine exhaust. Often, to regenerate the trap or filter, the captured particulate matter can then be burned by using heat from the engine or through other means.

[04] As shown in U.S. Patent No. 5,961,931, these particulate matter traps and filters typically include a mesh screen through which the engine exhaust is passed. The mesh screen filters the particulate matter from the engine exhaust.

However, to remove all particulate matter from the engine exhaust, the pores in the mesh screen must be small. As the pores get smaller, the pressure drop over the filter or trap increases, which results in a lower engine efficiency as more engine pressure is required to push the exhaust gas through the particulate filter or trap. Accordingly, the conventional filtration systems are best suited to remove large-sized particulate matter from an exhaust stream.

[05] However, in many internal combustion engines, including compression-ignition engines, some of the generated particulate matter may have a very small size and weight. This smaller-sized particulate matter has recently been the target of additional concerns, which restrict the amount of smaller diameter particulates that may be exhausted to the environment. Conventional particulate matter traps and filters are not necessarily well suited to remove the small diameter particulates since the size of the pores in the filters would have to be reduced.

[06] The method and apparatus of the present invention solves one or more of the problems set forth above.

Summary of the Invention

[07] One aspect of the present invention is directed to a method of agglomerating particulate matter in exhaust gas from an engine. A flow of exhaust gas from the engine is divided into at least two streams of exhaust gas. Each of the two streams of exhaust gas includes particulate matter. At least one characteristic of the particulate matter in at least one of the two streams of exhaust gas is altered, and the two streams of exhaust gas are combined such that the particulate matter agglomerates into larger particles.

[08] Another aspect of the present invention is directed to an apparatus for agglomerating particulate matter in an exhaust flow from an engine. The apparatus includes a first exhaust conduit that is configured to conduct a first stream of exhaust gas having particulate matter and a second exhaust conduit that is configured to conduct a second stream of exhaust gas having particulate matter.

A charging device is operable to selectively impart a positive charge to the particulate matter in the first exhaust conduit and to impart a negative charge to the particulate matter in the second exhaust conduit. A junction connects the first and second exhaust conduits to form a combined exhaust gas passage.

[09] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

Brief Description of the Drawings

[10] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the invention and together with the description, serve to explain the principles of the invention. In the drawings:

[11] Fig. 1A is a diagrammatic and schematic illustration of an apparatus for agglomerating particulate matter in accordance with one embodiment of the present invention;

[12] Fig. 1B is a diagrammatic and schematic illustration of an apparatus for agglomerating particulate matter in accordance with another embodiment of the present invention;

[13] Fig. 2 is a diagrammatic and schematic illustration of a charging device for altering the characteristics of particulate matter in accordance with an embodiment of the present invention;

[14] Fig. 3A is a cross-sectional view of an electrode disposed in an exhaust conduit in accordance with an embodiment of the present invention;

[15] Fig. 3B is a cross-sectional view of an electrode disposed in an exhaust conduit in accordance with another embodiment of the present invention; and

[16] Fig. 4 is a cross-sectional view of a junction illustrating the agglomeration of particulate matter in accordance with an embodiment of the present invention.

Detailed Description

[17] Reference will now be made in detail to embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[18] As illustrated in Fig. 1, an apparatus 10 for agglomerating particulate matter is provided. Apparatus 10 is connected to an engine 20. In the accompanying figures and description, the present invention is described in connection with a compression-ignition internal combustion engine. It is understood, however, that the principles of the present invention may be equally applied to any engine whose operation generates particulate matter, including, for example, a diesel cycle engine or a turbine engine. It is also understood that the principles of the present invention may be applied to turbo-charged engines as well as naturally aspirated engines.

[19] During operation, engine 20 produces a flow of exhaust, which is divided into two separate streams and directed into apparatus 10. The manner in which the exhaust flow is separated is dependent upon the configuration of engine 20. For example, as shown in Fig. 1A, an engine 20 with either a "V-type" configuration or an "in-line" configuration with a split manifold will produce two separate exhaust streams. Thus, an engine with a split manifold will divide the exhaust flow into two separate exhaust streams without requiring an additional flow divider.

[20] As shown in Fig. 1B, an engine 20 with an "in-line" configuration and a single manifold will produce a single flow of exhaust through an exhaust pipe 30. In this embodiment, an exhaust divider 34 divides the exhaust flow into two exhaust streams. Exhaust divider 34 may be any type of divider configured to split the exhaust flow from the engine into two exhaust streams. It may be beneficial to divide the exhaust flow from the engine into two substantially equivalent exhaust streams or into more than two exhaust streams.

[21] As shown in Figs. 1A and 1B, apparatus 10 includes a first exhaust conduit 24 and a second exhaust conduit 26. As shown in Fig. 2, a first exhaust stream 27 is guided into first exhaust conduit 24 and a second exhaust stream 29 is guided into second exhaust conduit 26. First and second exhaust conduits 24 and 26 may be separate pipes or may be part of a single pipe that includes a divider. For reasons that will become apparent in the following discussion, first and second exhaust conduits 24 and 26 may be insulated from each other.

[22] As shown in Fig. 2, first exhaust conduit 24 includes a ground 40 and second exhaust conduit 26 include a ground 42. Grounds 40 and 42 may be mesh screens that are made of an electrically conductive material, such as, for example, copper. As shown in Fig. 3A, ground 40 is disposed on the inner perimeter of first exhaust conduit 24. Similarly, ground 42 is disposed on the inner perimeter of second exhaust conduit 26. An insulating material, such as, for example, ceramic or rubber, may be positioned between ground 40 and first exhaust conduit 24 and between ground 42 and second exhaust conduit 26.

[23] As illustrated in Figs. 1A and 1B, a charging device 12 is provided. Charging device 12 is disposed along first exhaust conduit 24 and second exhaust conduit 26. Charging device 12 includes a positive electrode 14 and a negative electrode 16.

[24] As illustrated in Fig. 2, positive electrode 14 and negative electrode 16 are connected to a charging circuit 48. A positive connection 36 connects positive electrode 14 to charging circuit 48 and a negative connection 38 connects negative electrode 16 to charging circuit 48. Charging circuit 48 is configured to apply a positive voltage across positive electrode 14 and a negative voltage across negative electrode 16.

[25] In an exemplary embodiment, charging circuit 48 may be configured to apply a voltage having a magnitude of at least 7.5 kV to the positive electrode 14 and the negative electrode 16. It is expected that charging

circuit 48 may be part of the overall device that houses engine 20. For example, if engine 20 is part of an automotive vehicle, charging circuit 48 may be part of the vehicle electrical system and may be powered by operation of engine 20. Alternatively, charging circuit 20 may be powered by an independent power source, such as, for example, a battery.

[26] As shown in Fig. 2, positive electrode 14 is positioned within first exhaust conduit 24. As shown in Fig. 3A, positive electrode 14 may be substantially aligned with and may extend substantially parallel to the centerline of first exhaust conduit 24. Similarly, negative electrode 16 is positioned within second exhaust conduit 26 and may be substantially aligned with and may extend substantially parallel to the centerline of second exhaust conduit 26.

[27] As also shown in Fig. 2, a series of insulators 44, such as, for example, ceramic inserts, may be disposed between positive electrode 14 and first exhaust conduit 24 and ground 40. Similar insulators 44 are disposed between negative electrode 16 and second exhaust conduit 24 and ground 42.

[28] In another exemplary embodiment and as shown in Fig. 3B, each of the first and second exhaust conduits 24 and 26 may include a plurality of electrodes 15. The plurality of electrodes 15 in both first and second exhaust conduits 24 and 26 are connected to charging circuit 48. The plurality of electrodes 15 disposed within first exhaust conduit 24 may be positively charged while the plurality of electrodes 15 disposed in the second exhaust conduit 26 may be negatively charged.

[29] As illustrated in Figs. 2 and 4, first exhaust stream 27 flows through first exhaust conduit 24. First exhaust stream 27 includes particulate matter 46. The voltage applied to positive electrode 14 imparts a positive static charge to particulate matter 46, thereby creating positively charged particulates 52.

[30] Similarly, second exhaust stream 29 flows through second exhaust conduit 26. Second exhaust stream 29 also includes particulate matter 46. The

voltage applied to negative electrode 16 imparts a negative static charge to particulate matter 46, thereby creating negatively charged particulates 54.

[31] As shown in Figs. 1A, 1B, and 4, first exhaust conduit 24 and second exhaust conduit 26 are combined at a junction 18 to form a combined exhaust passage 28. The combination of first exhaust stream 27 and the second exhaust stream 29 at junction 18 causes the two exhaust streams to mix. A baffle or other mixing aid (not shown) may be disposed at junction 18 to aid mixing of the two exhaust streams.

[32] Referring to Fig. 4, when the first exhaust stream 27 and second exhaust stream 29 combine, the oppositely charged particulate matter 52 and 54 become mixed and collide with one another. The electrostatic charge of the particulate matter causes positively charged particulates 52 to be attracted to and combine with negatively charged particulates 54. The mutual attraction of the particulate matter causes the agglomeration of the oppositely charged particulates and the formation of combined particulate matter 56 that has a larger size, in terms of diameter, than the individual particulates before combination.

[33] Combined exhaust passage 28 may direct the combined exhaust flow into a particulate trap 22. Particulate trap 22 includes a filter element or similar mechanism configured to remove the combined particulate matter 56 from the exhaust flow. Because the apparatus of the present invention has combined the smaller particulates into larger combined particulate matter 56, the filter element of particulate trap 22 may have relatively large pores and still remove a majority of the particulates from the exhaust gas. The relatively large pores of the filter element translate to a lower pressure drop over particulate trap 22.

[34] In an exemplary embodiment and as illustrated in Fig. 4, apparatus 10 may include a single ground 43 that is positioned at junction 18. In this embodiment, a washcoat or an insulating insert 50 made of a material such as, for example, a ceramic or rubber, covers the inner perimeter of both of first and

second exhaust conduits 24 and 26. Insulating inserts 50 extend from positive and negative electrodes 14 and 16 to junction 18.

[35] Aspects of the above-described apparatus may be altered to further aid in the agglomeration of particulate matter 46 into larger combined particulate matter 56. For example, the electrical characteristics of particulate matter 46 may be altered through another type of charging device 12, such as, for example, a plasma charger.

[36] In addition, an electrical charge may be applied to particulate trap 22 to increase the ability of particulate trap 22 to remove particulate matter 46 from the exhaust stream. For example, a negative charge may be applied to particulate trap 22, while a positive charge is applied to particulate matter 46. Alternatively, a positive charge may be applied to particulate trap 22, while a negative charge is applied to particulate matter 46.

[37] In another embodiment, the temperature of particulate matter 46 may be decreased to improve the agglomeration of the particulate matter. The temperature of particulate matter 46 may be decreased through any means readily apparent to one skilled in the art. In one embodiment, the temperature of particulate matter 46 may be decreased by passing the engine exhaust stream through a turbocharger 32 (referring to Fig. 1B). As shown in Fig. 1B, the engine exhaust stream is passed through turbocharger 32 prior to entering apparatus 10. As is understood, turbocharger 32 will lower the temperature of the exhaust gas flow coming from engine 20. It is expected that particulate matter 46 may tend to agglomerate more efficiently when the particulate matter is at a lower temperature. If engine 20 has a split manifold or a "V-type" configuration, the exhaust flow from engine 20 may be combined and passed through turbocharger 32 and then divided by exhaust divider 34 into first and second exhaust gas streams.

Industrial Applicability

[38] The operation of the aforementioned system will now be described with reference to the attached drawings. After engine 20 is started, engine 20 will generate an exhaust flow that contains particulate matter 46. As shown in Figs. 1A and 1B, the exhaust flow is divided into first and second exhaust streams 27 and 29 either by the engine itself or by exhaust divider 34. First exhaust stream 27 is directed into first exhaust conduit 24 and second exhaust stream 29 is directed into second exhaust conduit 26.

[39] As shown in Fig. 2, charging circuit 48 applies a positive voltage to positive electrode 14 and a negative voltage to negative electrode 16. The applied voltages alter the characteristics of the particulate matter in first and second exhaust gas streams 27 and 29. A positive static charge is imparted to particulate matter 46 in first exhaust stream 27 and a negative static charge is imparted to particulate matter 46 in second exhaust stream 29. The characteristics of particulate matter 46 may also be altered through other mechanisms, such as, for example, a heating or cooling unit or a plasma system.

[40] As shown in Fig. 4, first exhaust stream 27 is combined with second exhaust stream 29 at junction 18. When the exhaust streams are combined, the particulates from one exhaust stream mix and collide with the particulates from the other exhaust stream. The altered characteristics of particulate matter 46 cause the particulates to be attracted to one another, for example, positively charged particulates 52 are attracted to negatively charged particulates 54. The attraction of the particulate matter results in the agglomeration of the smaller particulates into larger, combined particulate matter 56.

[41] The combined exhaust stream is then passed into particulate trap 22. Trap 22 removes the combined particulate matter 56 from the exhaust gas flow, thereby preventing the particulate matter from being vented to the environment. The particulate matter collected in trap 22 may be disposed of by

burning the particulate matter with heat from engine 20 or through another destructive process.

[42] As is apparent from the foregoing discussion, the apparatus of the present invention will therefore allow a conventional particulate trap to remove smaller diameter particulates from a flow of engine exhaust without an appreciable increase in the pressure drop over the particulate trap. Thus, the apparatus of the present invention will help meet newer particulate emission regulations, while having little or no impact on overall engine efficiency.

[43] It will be apparent to those skilled in the art that various modifications and variations can be made in the method and apparatus of the present invention without departing from the scope or spirit of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims and their equivalents.